THE TRADE WINDS IN PORTO RICO.

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Within a well-defined zone crossing the Atlantic and Pacific Oceans, mostly between the parallels of 10° and 25°, north latitude, the wind blows with great steadiness of force from an easterly direction. These winds have been known for centuries as the northeast trades, on account of the great advantage which they afforded sailing vessels in crossing the oceans from east to west. They have their best development over the open ocean, and are less marked in the vicinity of large land masses. The islands of the West Indies are wholly within the zone of the northeast trades, while Porto Rico and the numerous smaller islands to the east and south lie within those portions showing their most characteristic features.

THE DIRECTION OF THE TRADES.

The prevailing direction of the wind throughout the year in Porto Rico is between east and southeast. The direction varies somewhat with the season of the year and with the hour of the day, but the variations are not great. The changes in direction and force of the wind noted in the following paragraphs are based upon hourly observations at San Juan during a period of 10 to 12 years. While observations in other portions of the island might show slightly different results, the conclusions based upon the San Juan data can be safely accepted as representative of the entire island.

From 9 a. m. to 10 p. m. the prevailing direction is from the east for the entire year, and from 10 p. m. to 9 a. m. it is from the southeast. These directions are remarkably uniform in so far as they refer to average conditions for monthly periods. The night winds, being lighter, vary somewhat more than those of the day. The months of October and November are apt to show the greatest departures from the normal direction, both months having a considerable percentage of south winds, especially during the early morning hours. During the winter months the percentage of northeast winds increases, sometimes to the extent of becoming the prevailing wind for the entire month. The diurnal change in direction from southeast to east occurs between 9 a. m. and 10 a. m. during the greater portion of the year, but begins an hour earlier in the months of June, July, and August and an hour later in January, October, and November. During July and August the prevailing east wind extends far into the night—to 1 or 2 o'clock in the morning.

The departures from the normal easterly direction are usually for short periods of a few hours or a day or two, and occur mostly during the passage of cyclonic disturbances during the hurricane season, or of storms of great severity which cross the north Atlantic along a more southern route than usual.

Sometimes periods of light, variable winds and unsettled weather continue for several days; these periods are most frequent in the months of May, October, and November, when the high humidity and light winds produce an oppressive atmosphere. The temperature, as indicated by the thermometer, is not much above the normal, but, owing to the absence of the usual fresh breezes, evaporation from the skin is checked and the usual lowering of the skin temperature, or sensible temperature as it is called, does not take place. The following figures express the duration of stated wind directions in terms of the percentage of the possible number of hours within the period of a year:

Winds.	Per cent of time.	Winds.	Per cent of time.
North	2	Southwest	5
Northeast	11	West	1
East	38	Northwest	1
Southeast	28		
South	14		100

The above table shows a prevailing direction from the northeast to southeast during 77 per cent of the entire year, or an aggregate of 281 days; of 14 per cent, or 51 days, from the south; of 2 per cent, or 7 days, from the north; and of 7 per cent, or 26 days, from a direction between southwest and northwest. The prevailing directions for periods of a month during the past 12 years are shown in the following table:

Prevailing monthly wind directions.

[For 12 years.]

Direction.	Jan.	Feb.	Mar.	Apr.	May.	June.
	Times.	*Times.*	*Times.*	*Times.*	*Times.*	*Times.*
Northeast	3	1	2	0	0	0
East	8	9	9	8	6	8
Southeast	1	2	1	4	6	4
South	0	0	0	0	0	0

Direction.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	Times.	*Times.*	*Times.*	*Times.*	*Times.*	*Times.*	*Times.*
Northeast	0	0	0	0	2	3	0
East	11	12	6	2	7	7	10
Southeast	1	0	6	7	2	2	2
South	0	0	0	3	1	0	0

WIND DIRECTION AND TEMPERATURE.

The changes in temperature due to change in the direction of the wind are as a rule very small, a result to be expected from the geographical situation of the island within a very extensive region of a remarkably uniform temperature. The decrease in temperature from the Equator northward and southward is slight up to quite high latitudes, especially over the oceans. Departures from the normal temperature accompanying changes in the direction of the wind become fairly well marked, however, during the longer periods of northerly or southerly winds. The comparatively low temperatures experienced are most likely to occur during calm and clear nights, when the radiation from the ground is most active, while the high temperatures occur during periods

of sluggish air movement, accompanied by bright sunshine.

THE VELOCITY OF THE TRADES.

Wind velocity is quite as uniform in Porto Rico as wind direction. The average hourly velocity throughout the year is a little short of 11 miles. The entire range in average monthly velocities during the course of the year is between a minimum of 8 miles in October and a maximum of 13 miles in July, as shown in the following table:

Average monthly wind velocity.

	Miles per hour.
January	11
February	11
March	12
April	11
May	11
June	12
July	13
August	12
September	10
October	8
November	9
December	10
Year	11

The diurnal variation in the force of the wind is naturally a well-marked feature of the trades, as it is at all land stations; the average annual minimum velocity, 6 miles, at San Juan, occurs at sunrise, and the maximum, 16 miles, occurs at about 2 o'clock in the afternoon. These values are greatest during the month of July, 7 miles and 18 miles, respectively, and least in October, 5 miles and 13 miles, respectively. The remarkable uniformity in the wind movement is also shown by the figures expressing the average hourly velocities for successive years. The difference between the highest average for an entire year and the lowest average hourly velocity is but 1.6 miles, namely, 11.6 miles in 1906 and 10 miles in 1901 and 1902. The highest and lowest average hourly velocities for any one month during the past 11 years are shown in the following table:

	Jan.	Feb.	Mar.	Apr.	May.	June.
Highest	15	14	14	13	13	14
Lowest	9	9	10	9	9	11
Range	6	5	4	4	4	3

	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Highest	14	13	11	9	13	14	12
Lowest	11	10	8	6	7	8	10
Range	3	3	3	3	6	6	2

The east wind is the strongest throughout the year, and the southwest wind the lightest, considering average monthly values.

The relative force of the wind from the different points of the compass is shown in the following table in miles per hour:

Wind direction:	Wind force.
North	8
Northeast	13
East	14
Southeast	8
South	5
Southwest	4
West	5
Northwest	7

HIGH WINDS.

As cyclonic disturbances are not of frequent occurrence in the vicinity of Porto Rico, high winds are not as common here as in the domain of the United States. The period from November to June is practically free from the West Indian hurricanes, while comparatively few occur in July and October in the vicinity of Porto Rico; August is the month of greatest hurricane probability, but even during this month the island has been entirely within the storm area but three times during the past 40 years.

Moderately high winds frequently occur over portions of the island, however, during the passage of severe storms within a distance of 100 or more miles to the south or north. A tabulation of the highest velocities occurring within each month during the past 12 years shows the occurrence of a gale, a velocity of 40 or more miles per hour, on only 16 occasions, or an average of one in about 10 months. The wind attained a velocity of 50 miles on only five occasions during the same period. These velocities are based upon a maximum rate for a period of five minutes. The average monthly maximum velocity is 33 miles per hour. The highest wind velocity recorded at San Juan from November, 1898, to the close of 1910 is 72 miles per hour. This velocity was maintained for five minutes during the local storm of the character of a tornado which passed over the city on the 6th of September, 1910. The highest velocity recorded at San Juan during the hurricane of August 8, 1899, was 66 miles per hour; the recording instrument did not, at that time, have the same unobstructed exposure, otherwise a velocity of about 75 miles would doubtless have been recorded. The highest velocities have most frequently occurred with an east or northeast wind, although high southeast winds are of almost equal frequency. Of the 16 occasions on which the wind attained the velocity of a gale, 4 are credited to the month of August, 3 to September, 2 each to June, July, and October, and 1 each to January, March, and November. No gales have been recorded in the past 12 years in the months of February, April, May, and December.

THE DEPTH OF THE TRADE WINDS.

Judging from the movement of the clouds over San Juan, the average depth of the trade-wind current probably does not exceed 10,000 feet. The lower clouds, stratus, cumulus, and strato-cumulus, are wholly within the trade-wind drift. The bases of these clouds are generally below the level of the neighboring mountain summits, or under 3,000 feet. Excepting the well-developed cumulus clouds, whose heads frequently penetrate the intermediate layer of alto-stratus clouds, it is probably safe to state that the lower cloud belt is generally confined between the limits of 3,000 and 5,000 feet.

Tabulating the record of the 9 a. m. cloud observations at San Juan during the past 10 years, we find that the lower clouds moved from the east at 74 per cent of all observations, and from the southeast at 22 per cent, leaving but 4 per cent for all other directions.

The upper clouds, the cirrus forms, have an almost equally uniform movement from a westerly direction: 66 per cent from the west, 16 per cent from the southwest, and 9 per cent from the northwest, leaving but 9 per cent for all other directions.

The record of observations of the intermediate layer of clouds, the alto-cumulus and alto-stratus, shows a more uniform distribution between an easterly and a westerly

direction: From the northeast, 5 per cent; the east, 35 per cent; the southeast, 2 per cent; the southwest, 10 per cent; the west, 20 per cent; the northwest, 6 per cent; or 60 per cent from an easterly and 36 per cent from a westerly direction.

Very little difficulty is experienced by the observer in the classification of the lower and of the very high clouds. The personal equation of the observer plays an important part, however, in the classification of the clouds of the intermediate layer. In form and in texture the alto-cumulus and the alto-stratus often closely resemble some of the cirrus forms, especially in the early stages of development of the former. The elevation, however, of the alto-cumulus and alto-stratus does not entitle them to be classed as cirrus clouds, as they are probably in very many instances under an elevation of 10,000 or 12,000 feet. In the judgment of the writer a large percentage of the clouds recorded as cirro-cumulus and cirro-stratus really belong to the intermediate layer; if so, the percentage of westerly winds for this middle layer should be increased considerably. The personal impression, gained after two years' residence in Porto Rico, is that the prevailing direction of movement of the intermediate clouds is decidedly from the west and southwest.

THE SANITARY VALUE OF THE TRADES.

The value of the trade winds as an aid to navigation has been generally recognized for a very long time. As early as the fifteenth century navigators took advantage of the winds in the lower latitudes in their voyages to the West Indies.

The beneficent effect of a uniform and moderate wind movement upon the general health and the personal comfort of residents within the Tropics is not yet generally and sufficiently recognized by those living in extra-tropical regions. The uniformly high temperatures of the tropical belt, combined with a high humidity, have a decidedly debilitating and depressing effect in the absence of the modifying and stimulating effects of the trade winds or the daily recurring land and sea breeze.

The temperatures in Porto Rico are not excessively high, but the amount of moisture in the atmosphere, or the humidity, is quite high at all times. It is the presence of the steady, moderate flow of the trade winds which takes Porto Rico out of the class of areas in the Tropics to be avoided by the white man, and makes of it for more than half the year a very desirable place of residence for business as well as for pleasure.

During the brief periods of a few days, especially in the months of May, October, and November, when the trades decrease in strength, the effect of the more sluggish movement of the air is at once felt in increasing lassitude and a disinclination to exertion of any kind. As soon as a breeze springs up, however, the feeling of depression vanishes, even in the intense sunshine. Shade and a moderate breeze are sufficient to insure personal comfort in any season of the year in Porto Rico, so far as the usual atmospheric conditions are concerned. Exposure to the sun should be avoided as much as possible, especially by those not accustomed to residence in the Tropics; neglect of this necessary precaution is the cause of many disappointments to new arrivals.

In general healthfulness Porto Rico compares very favorably with the large cities of northern climates. During the past 10 years the annual mortality rate for the island as a whole has been about 23 per 1,000 inhabitants, practically the same as that of such cities as Boston, Philadelphia, Baltimore, and many other American and European cities. The island has been comparatively free from epidemics of any extent or degree of severity, a somewhat surprising fact in view of the very insanitary conditions which exist in some of the more congested centers of population. Few people realize the density of population in Porto Rico. With a total area of about 3,600 square miles, there are about 1,200,000 inhabitants, an average of over 300 to the square mile. In addition, there are few cities of any size; the population is mostly rural. San Juan, the largest city, with its suburbs, has a population of about 50,000, and covers an area of less than half a square mile.

The prevalent diseases of the island, excepting tuberculosis and the hookworm disease, are mostly intestinal disorders. In the language of one of the resident physicians the diseases of Porto Rico are those of the summer season in the temperate region, rather than the diseases peculiar to tropical countries. Eternal vigilance in the inspection of food and drink is the price of good health here as elsewhere in the Tropics. With the steady improvement in sanitary conditions, which has been a marked feature of the rapid development of Porto Rico, the dangers accompanying life in the Tropics are fortunately growing steadily less. The climatic conditions are favorable for good health, though there is lacking the bracing effects of the lower temperature and drier atmosphere of more northern countries.

While it is highly probable that the efficiency of the laboring classes in Porto Rico is distinctly below that of the same classes in more northern climates, the lower rating is without doubt largely due to the prevalence of the hookworm disease, to insufficient nutrition, a low rate of compensation, and the lack of modern methods of supervision; that is, to conditions under the control of man, rather than to climatic conditions.

THE TRADE WINDS AS A MOTIVE POWER.

The constant and remarkably uniform flow of the trade winds gives them an additional value in Porto Rico. The use of the windmill for furnishing power is gradually receiving proper recognition. The south side of the island is comparatively dry, and the rainfall is irregularly distributed through the year, necessitating extensive irrigation operations in order to carry on successfully the cultivation of sugar cane and other crops. On the north side the problem of drainage is almost equally important. In both of these operations the pump can be utilized to great advantage, owing to the presence of a constant wind as the motive power. Water is available in abundance on the south side coastal plain at depths varying from 50 to 100 feet, and the winds offer an inexhaustible source of power for pumping it to the surface. The windmill is also an economical engine for providing power on plantations for general purposes, where the use of steam may prove to be too expensive. When the availability of the trade winds as a source of power becomes more generally recognized, the windmill will be a much more familiar sight in Porto Rico than it is to-day.

THE EXPLANATION OF THE TRADE WINDS.

The development of the theory of the trade winds from the first scientific explanation read before the Royal Society of London in 1735 by George Hadley, to within comparatively recent years, forms a very interesting chapter in the history of the science of the weather.

The difference in the temperature of the atmosphere at the Equator and the zones to the north and south was recognized as the primary cause of the trades, and the revolution of the earth about its axis as the secondary cause. A clear understanding of the forces and conditions which

produce the northeast and southeast trades was, however, not worked out until a much later period; not until simultaneous observations of the barometer and wind direction and force became available, over a hundred years later, did it become possible to evolve a correct theory of the general circulation of the atmosphere, of which the trades form but a small part.

The general movements of the atmosphere and the causes which give rise to changes in wind direction and force are now fairly well understood. Over the North Atlantic there is a permanent area of high barometric pressure, or anticyclone, as it is technically called; in the equatorial zone the atmospheric pressure is permanently low; the flow of the atmosphere southward from the area of high pressure into the equatorial area of low pressure, in an endeavor to restore atmospheric equilibrium, constitutes the North Atlantic trade wind. The rotation of the earth from west to east deflects this wind from a north wind to a northeast, east, or a southeast wind, depending upon the locality with reference to the center of the North Atlantic area of high pressure. This area of high pressure, while permanently located in the North Atlantic, shifts its position within limited bounds from month to month and from year to year, causing the observed variations in the prevailing direction of the trades. At the same time there are variations in the gradient of pressure, or the difference in pressure, between the center and edges of the high area, causing variations in the velocity of the trades.

LAND AND SEA BREEZES.

Owing to the strength and persistence of the trade winds and the small extent of the coastal plain, the land and sea breezes are not a marked feature of the diurnal wind movement in Porto Rico. Their effects are, however, clearly seen in the prevailing direction of the wind on the north and south sides of the island. The resultant wind direction over Porto Rico, judging from the movement of the lower clouds, is from the east-southeast. The prevailing direction at San Juan is from the east during the day, and from the southeast during the night. These deviations, at the surface of the earth, from the true direction of the freely moving atmosphere above the island are in accord with the theory of the land and sea breeze. During the daytime there is a tendency along the north coast to blow from the relatively cooler ocean toward the warmer coastal plain; the result is a deflection of the east-southeast trade to an east wind. During the night the tendency is to blow from the relatively cooler land area toward the warmer ocean, resulting in a deflection of the trades from east-southeast to southeast.

On the south side the tendency to deflect the trade is reversed. There are no hourly observations available along the south coast, but the prevailing direction as recorded at practically all of the stations is from the southeast, based upon observations made during the day. It is probable that the prevailing direction during the night and early morning hours is from the east.